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ABSTRACT

This manual provides information needed to meet specific standards for certification as a pesticide applicator. The text is directed to individuals working in demonstration and research pest control who evaluate, provide and disseminate information on pest control procedures. Guidelines for designing and conducting a research experiment in pesticide effectiveness are outlined. (CS)

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Iowa
Commercial Pesticide Applicator Manual

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CATEGORY 10

DEMONSTRATION AND RESEARCH

This manual is to be used for certification training in conjunction with the U. S. Department of Agriculture – U. S. Environmental Protection Agency manual, **Apply Pesticides Correctly,** EPA-335.

Cooperative Extension Service
IOWA STATE UNIVERSITY
Ames, Iowa 50011

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This manual has been developed for individuals wishing to become certified in commercial pesticide applicator category 10, Demonstration and Research Pest Control. It contains specific information than an individual must know before becoming certified in category 10. The manual has been designed to supplement the general information contained in the core manual **Apply Pesticides Correctly—A guide for commercial applicators** (plus an Iowa State University supplement) and should not be used for certification preparation without referring to the core manual as well.

Individuals becoming certified in category 10 must also become certified in an additional category applicable to their particular activity. For example, an individual wishing to do demonstration and research work in agricultural weed and insect control, must become certified in not only category 10, Demonstration and Research Pest Control, but also category 1A, Agricultural Weed Control and category 1B, Agricultural Insect Control.

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Prepared by Jerry DeWitt, pesticide training coordinator, who expresses appreciation to the University of Georgia for use of source material.

INTRODUCTION

Individuals working in demonstration and research pest control not only evaluate, provide, and disseminate information on pest control procedures, but also serve as examples for other individuals who apply restricted-use pesticides. The Demonstration and Research Pest Control catagory includes:

- people who demonstrate to the public the proper use and techniques of applying restricted-use pesticides or supervise such demonstration, and
- people who conduct field research with pesticides or supervise the use of restricted-use pesticides.

The first group includes Cooperative Extension personnel (county extension directors, area crop production specialists, state specialists, etc.), vocational agriculture instructors, community college agriculture instructors, industry representatives, and others who demonstrate effective pest control practices. The second group includes Iowa State University, community college, state, federal, and industry researchers, and others who conduct research in the field using restricted-use pesticides.

PESTICIDE-ORGANISM INTERACTIONS

Both the beneficial and harmful effects of pesticides are determined by pesticide-organism interactions or how pesticides and organisms react to each other. To do its job, a pesticide must actually (1) penetrate the organism, (2) move or be transported to the site of action, and (3) there disrupt or alter a vital function. The manner in which the pesticide affects the vital function is called its mode of action. Penetration, transport, and mode of action involve pesticide-organism interactions. Pesticide-organism interactions are also involved in the metabolism, accumulation, and elimination of pesticides by the organism as well as in biodegradation and biological magnification.

Selectivity (the ability of a pesticide to kill or otherwise alter one organism and not another) and the development of pesticide resistance are often caused by differences in pesticide-organism interactions.

Penetration and Uptake

The speed and extent of penetration depends on the permeability of the organism to the specific pesticide. This permeability differs significantly among plants and insects and even among different tissues of the same organism. Among animals, tissues of the respiratory and digestive system are usually much more permeable than the skin. With plants, hardened growth and bark generally provide a more effective barrier than

new and succulent growth. The ability of a pesticide to penetrate an organism depends on its chemical nature and the formulation. Penetration is usually increased by organic solvents.

Transport

The movement of the pesticide from the place where it entered the organism to the site of action involves several factors. The motility of the pesticide molecule is important and varies among pesticides. The efficiency of the transporting mechanism of the plant or insect is also important.

Mode of Action

The pesticide performs its main function only after it reaches the site of action within the organism. This is usually the protoplasm of a living cell and often a particular kind of cell. For example, the site of action for organophosphate insecticides is the nerve cell.

Pesticides kill or otherwise alter an organism by disrupting or interfering with some vital physiological function. This is called the pesticide's mode of action. As an example, the mode of action of organophosphate insecticides (methyl parathion, malathion, Thimet, etc.) is the inhibition of cholinesterase, an enzyme that is essential in regulating the nervous system. When cholinesterase is inhibited or tied up, muscles and

glands become extremely overactive because of excessive stimulation by the nerve cells. Some

herbicides are plant growth regulators that speed up or slow down cell growth and reproduction. Other herbicides may be desiccants, defoliants, or antitranspirants. Fungicides may act as enzyme poisons, spore germination inhibitors, etc.

Metabolism

Metabolism is the process by which a pesticide, or another chemical, is changed into one or more different chemicals within a living organism. The metabolic product, or metabolite, may be either more toxic or less toxic than the original pesticide chemical. Aldrin, for example, converts to dieldrin. Some pesticides are effective only after they have been metabolized to a lethal compound by the organism. Given enough time, most organisms can metabolize most pesticides to nontoxic metabolites. Survival of the organism may depend on whether or not the organism can metabolize the pesticide into nontoxic metabolites before the toxic activity is complete or irreversible.

Resistance is the inherent ability of the pest to sustain less damage to pesticide application than others under comparable environmental conditions. Resistance to pesticides is most common in insects and mites. More than 220 insects or mites are known to be resistant to various pesticides in the United States. In Iowa, corn rootworm resistance to chlorinated hydrocarbons has been known since the late 1960's. Resistance often develops in pest populations that have been frequently treated with a single pesticide. Development of resistance in pest populations may sometimes be averted or delayed by:

- reducing the numbers of treatments,
- alternating pesticides used.

Accumulation, Elimination, and Detoxification

Pesticide chemicals and their metabolites may be stored or accumulated within the organism or be eliminated as waste. If the level of exposure to most accumulative pesticides remains constant, an equilibrium between storage, metabolism, and elimination will be reached, and the concentration of the pesticide and its metabolites will remain constant within the organism. If the level of exposure is changed, then the concentration within the organism will correspondingly increase or decrease.

Because residues may accumulate within organisms, special precautions in harvest or slaughter must be observed with the treated commodities. Harvest, slaughter, and freshening intervals provide the necessary time for metabolites to be broken down or eliminated before safe consumption of the treated product is allowed.

Biodegradation

Pesticides in the environment can be affected

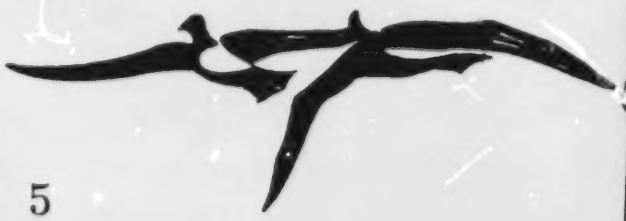
by various conditions:

- soil organic matter (Soils with high organic content require higher rates of pesticide application.),
- soil pH,
- soil texture (Silts and clays have more surface area and require higher rates.),
- ultra-violet light,
- soil bacteria, fungi, and actinomycetes,
- soil microfauna,
- other microorganisms,
- soil moisture,
- temperature, and
- humidity.

These factors not only affect the efficacy of the pesticide but also determine the manner and rate that it is metabolized. Biodegradation is simply metabolism, but generally it more specifically refers to the decomposition of a pesticide residue in the environment by bacteria and other microorganisms that use it for nutritional purposes.

Biological Magnification

Biological magnification is an interesting pesticide-organism interaction. It is the tendency



for certain pesticides to progressively become more concentrated in each type of organism when moving from the bottom to the top organism within a food chain. DDT is an example in this respect.

DDT in Lake Michigan is probably one of the best examples of biological magnification of a pesticide. The bottom sediments have been found to contain an average of 0.0065 ppm. Small invertebrates averaged 0.41 ppm while predacious fish such as coho salmon and lake trout contained 3 to 8 ppm. Herring gulls, at the top of the food chain, contained as much as 3,177 ppm of DDT. In this case, the overall magnification from the bottom sediment is about 370,000-fold. Biological magnification has been suspected in deaths and reproductive failures among predatory animals, especially hawk-like birds and brown pelicans. Perhaps the most familiar example of reproductive effects is its frequent association of thin eggshells with certain organochlorine insecticides.

Awareness of this pesticide-organism interaction is important when working with certain pesticides.

INTEGRATED PEST CONTROL

Properly planned and executed, integrated pest management practices can sometimes main-

tain pest populations at a level low enough to satisfy human needs with minimal adverse effects on nontarget organisms and on environmental quality. Integrated pest management can be more effectively accomplished if the agricultural crop or other site of a pest problem is considered in its entirety and not merely an arena in which to embattle a pest. Past, present, and future conditions or practices tremendously affect the level of pest populations, the choice of pest control methods, and the degree of pest control achieved.

It should be recognized that any pest control practice, including the application of pesticides, will have effects other than the intended one. Such side effects may be good or bad, gross or slight, short-lived or long-lived, local or distant, obvious or nebulous. The demonstrator and researcher should be ever observant for these side effects and consider them in interpreting, reporting, demonstrating, and recommending pest control practices. Integrated pest management implies the selection of those pest control measures that will maximize beneficial effects and minimize harmful ones. Individual elements or control measures within the integrated pest management program should be selected, used in the proper sequence, and timed to be compatible with each other, with other cultural or maintenance practices, and with use of the item that is being protected from pests. Neither pesticides nor any other individual control measure should be overused to the extent that it loses its effectiveness, interferes with the effectiveness of other control measures, or adversely affects man, other nontarget organisms, or the environment.

Pesticides are probably more subject to being overused or misused than the other pest control methods. Such misuse or overuse may not only result in unnecessary harm or hazard to man and his environment but can result in poor pest control or even a higher incidence of pest attack.

Resurgence of target pest populations or population explosions among secondary pests or nontarget pests may follow pesticide applications because of the destruction of natural enemies.

Parasite and predator populations may survive a pesticide application but be decimated by

starvation when the pests and other hosts are killed off.

In certain instances, an organism is not an important pest simply because of competition from another organism. Such an organism becomes a pest when its competition is removed. If broadleaf weeds are selectively killed by a herbicide, grassy weeds will usually thrive. Some pests that occur on crops late in the season are pests because the crop has been protected from competitors.

In some instances, a pest may be supporting another organism that becomes a pest when its host is controlled. Weeds and grasses may harbor insects such as stalk borers and armyworms that move to corn when the weeds are destroyed.

The certified applicator in demonstration and research pest control must be ever mindful of the extreme complexity of the usual environment in

which pest control is practiced. Biological phenomena, climate, topography, various physical and chemical characteristics, maintenance or cultural practices, and use patterns are so interrelated that it is extremely difficult to adequately assay the effects that a pesticide may have on the ecosystem. One must be constantly alert and thoughtful in developing, recommending, and demonstrating pest control practices.

SETTING UP AN EXPERIMENT

Before conducting a field experiment with pesticides, it is best to prepare a statement that

answers the following questions:

1. What are the objectives? (What do you want to prove or demonstrate?)
2. What is the design? (How are the treatments and plots arranged?)
3. What variables exist within either the experiment or the plot area? (Are there soil or varietal differences?)
4. How many replications are needed? (Two, four, or more?)
5. What is the sampling procedure? (Number of weeds per square foot or yields?)
6. How will the data be analyzed? (Analysis of variance statistically, or simple number comparison?)
7. How will the results of this experimental work be used? (Publication, sales, or demonstration?)

The importance of the last question cannot be overemphasized. The intended use of the data collected in the experiment will greatly affect your answers to other questions. For example, an experiment designed to show that the yield increase was due to pesticide use will involve a different experimental plot design, greater numbers of replications and a different sampling procedure than an experiment designed to illustrate the possible use of a pesticide in combination with a new tillage practice.

Nonreplicated trials or trials without control plots are not experiments. These trials do not contain comparisons where the treatment was not used, nor do they sample the variation within a test area. Although such trials are *not* acceptable for publication or sales promotion, they may be valuable in certain instances such as demonstration plots.

An observation trial may be used to determine if a new practice or product shows promise and is worthy of testing in a full scale, replicated, and randomized experiment.

A result demonstration trial is an attempt to show by example (generally to the producer) the practical application of an established fact. This type of trial is commonly used as an important training tool in the Cooperative Extension Service.

Definitions

You should be familiar with these terms in setting up experimental or demonstration pest control work.

Bias—A manipulation of the experiment so that results do not accurately reflect the effect of a treatment.

Block—A group of experimental units or plots in which each treatment occurs the same number of times.

Check or Control—The experimental units or plots to which treatments *are not* applied.

Experimental Error—An inconsistency inherent in an experiment that may prejudice results.

Plot—The experimental unit; e.g., the area of a field or a group of animals receiving a treatment.

Randomization—A random arrangement of treatments by purely objective methods; e.g., drawing numbers out of a hat.

Replication—The same treatment appears two or more times in an experiment.

Sample—Representative unit(s) taken from a population; e.g., the number of velvet leaf plants or corn borers counted in each plot.

Result Demonstration Trial—A nonreplicated trial used to demonstrate some established fact or principle.

Treatment—The factor being tested in an experiment; e.g., type of herbicide or fungicide.

Trial—An experiment. A group of plots to which treatments have been applied.

EXPERIMENTAL DESIGN

Designing an experiment is an extremely important step because errors made in the design can invalidate the results of the entire experiment. The most able statistician cannot assist you in reaching valid conclusions from an improperly designed experiment. It is generally best to avoid complex experiments or demonstrations which involve elaborate designs. If you have trouble with a design or are in doubt about its validity, seek assistance before initiating the research.

The *completely randomized design* is the most simple design (Fig. 1). It is set up by assigning treatments at random to a previously determined set of plots. Any number of treatments may be tested in this design. It is desirable to assign the same number of plots to each treatment, but it is not essential. This is not usually the most efficient design for research in field crops and may be better suited for trials with livestock.

The advantages of this design are that it is flexible and simple. The estimation of the experimental error with this design may be less precise than with other designs.

When the plots are laid out within a field, the number of plots is determined by multiplying the number of treatments by the number of replications of each treatment; e.g., 18 treatments of herbicides x 3 replications = 54 plots. The treatments are assigned to the plots at random.

The *randomized complete block design* is used to keep variability among plots in a block as small as possible (Fig. 2). In this design, the treatments are assigned at random to a group of plots called a block. Because adjacent plots usually yield more alike or have more similar disease or pest infestations than those separated by some distance, the block is kept as compact as possible. This is accomplished by placing the plots, usually long and narrow in shape, close together. It is desirable to obtain a compact block. Thus, treatments shou'd be as few as possible.

Plots can be laid out as strips through a field. This design will provide highly reliable data but will become cumbersome with a large number of

Fig. 1. Completely randomized design with three herbicides—Cobex, Lasso and Treflan, and control plots.

treatments—usually more than five to six. Note that each treatment occurs once in each block.

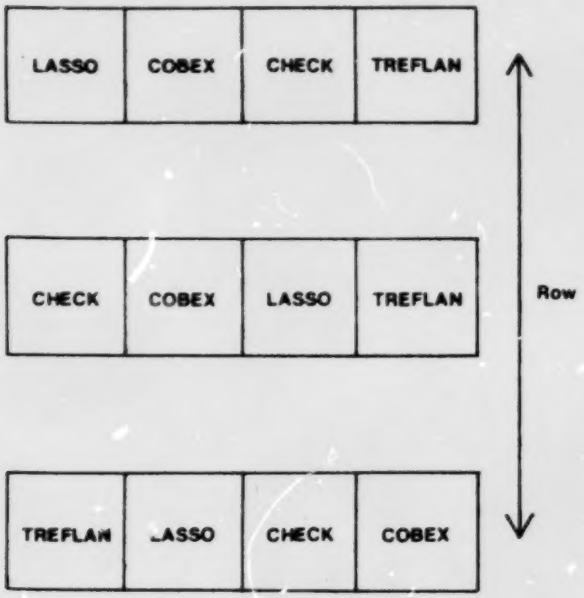


Fig. 2. Randomized complete block design with three herbicides—Cobex, Lasso and Treflan, and control plots.

The *Latin sqaure design* groups treatments in two different ways—by columns as well as rows (Fig. 3). Every treatment occurs once in each block (row) and once in each column. Variability across the experimental area is measured and removed in two directions. With the Latin square design, the number of treatments must equal the number of replications. With a large number of treatments this design becomes cumbersome. Usually, this design is used for experiments where there are from four to eight treatments.

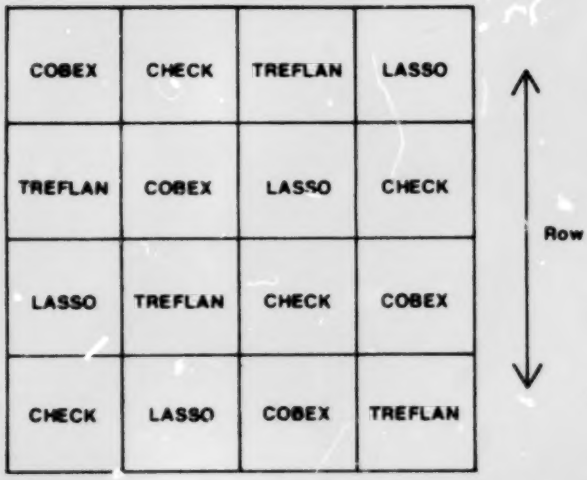


Fig. 3. Latin square design with three herbicides—Cobex, Lasso and Treflan, and control plots.

RANDOMIZATION

Many factors might affect the outcome of experimental field work—soil type, drainage, compaction, erosion, pest infestation, temperature variation, etc. Such factors may change with time and with location in a field. The researcher or individual involved in pest control demonstration work must be constantly alert in selecting plots in order to avoid selecting ones that may differ from others. These sources of bias may be minimized by *randomization*. This is the process of determining which experimental plots or units are to receive a given treatment by a purely random fashion. This may be done by tossing a coin, casting a die, drawing cards or numbers, or using a table of random numbers. When randomizing plots, avoid systematic arrangements such as regularly alternating two treatments or repeating several treatments in the same order. Avoid selecting a group of numbers that "look as though they ought to be random."

CONTROL OR CHECK PLOTS

The experimental units or plots to which the treatment is not given are called the control or check. Inclusion of control plots is mandatory in

all statistically sound experimental field work. Failure to include control plots or the incorporation of inadequate control plots provides only questionable results unacceptable for publication and sales promotion. The selection of check plots or units should be made with the same objectivity as that of other plot selection. The same variable factors that may affect treatment plots will affect control plots. Control plots should not be arbitrarily located near a fence row, lane, gate, or simply in the middle or side of the field.

CALIBRATION

Correct calibration and accurate measuring and mixing of pesticides are extremely important in research and demonstration pest control work. Although the hazards of application may be reduced and the chances of nontarget pollution minimized in small plot work the chances of misapplying the correct rate of pesticide are generally increased. Small errors in measuring the candidate material, for example, may cause over- or under-dosing of the treatment plot. Small errors in calculations are greatly magnified in small plot research. The addition of two fluid ounces of a can-

didate herbicide in a 100 gallon tank of water during mixing for general field application may not necessarily be significant. This small amount, however, added to two quarts of water in small plot research can result in highly inaccurate results.

Measuring of candidate pesticides for small plot or research work often demands the ability of the researcher to work comfortably with measurements of grams, milliliters, or ounces rather than pints or pounds.

Rough estimates or "rounding off" in the measurement of pesticides for research or demonstration is not an acceptable practice.

Liquid measurements should be made with graduated cylinders or pipettes. Safety pipette fillers or propipettes should be used with pipettes in order to avoid the inadvertant introduction of the pesticide into the mouth of the researcher.

Dry materials should be measured on properly adjusted scales that provide measurements in milligrams, grams, or ounces.

APPLICATION AND SAMPLING TECHNIQUES

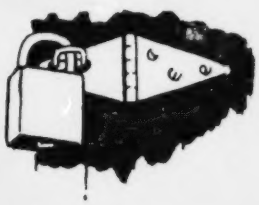
A well-designed experiment can lose its value through careless techniques of treatment application and data sampling or collection.

- Carefully label all plots or experimental units.
- Avoid nonuniform applications.
- Clean application equipment between treatments.
- Avoid inadvertent factors such as unequal preparation, treatment, or maintenance of the check plots.
- Require one individual to make all treatments.
- Avoid terms such as "severe, moderate, slight."
- Define indices clearly.
- Require one individual to take all samples. If more than one individual is involved, do not allow one individual to sample all replications of one treatment.
- Sample at the same time (hour, day, etc.).
- Do not pool or bulk samples initially.

SAFETY

Individuals involved in research or demonstration pest control are not considered to be exempt from following standard safety precautions in:

- measuring and mixing pesticides,
- calibration of equipment,
- application,
- equipment cleanup,
- disposal, and
- safe storage.



Common sense dictates that the researcher practice good safety techniques when handling these pesticides because some materials may be experimental or numbered compounds and not previously familiar to the applicator.

The minimum safety equipment that should be *available* and *used* when working with these pesticides is:

- neoprene gloves,
- respirator,
- hat,
- long-sleeved shirt or jacket,
- coverall-type garment, and
- goggles or face shield.

A supply of water, soap, and a towel should be available at the application site for normal cleansing or for emergency decontamination of spilled pesticides.

Neither the small amount of area treated nor the limited amount of pesticide used in demonstration and research work precludes following safe application procedures. All pesticides can result in acute or chronic injury or even death in humans.

Before mixing and applying pesticides in research work, the investigator should read the label and be aware of:

- the acute oral and dermal toxicity of the compound (oral and dermal LD_{50}),
- inhalation toxicity (LC_{50}),
- special hazards, and
- antidotes.

Knowledge of these factors will give the researcher valuable insight in safe handling, application, and disposal procedures with ex-

perimental materials. Most importantly, this information will help prevent serious injury or death to the researcher and applicator.

DISPOSAL

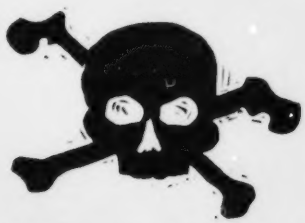
Excess pesticides and containers used in research and demonstration pest control must be disposed of properly. Proper disposal consists of:

- burial in an Iowa Department of Environmental Quality-approved sanitary landfill,
- incineration at an approved site (None are currently approved in Iowa.), or
- returning to cooperating industry (experimental materials).

Excess mixed pesticides should be collected at the application site and sealed in appropriate containers for later disposal at an approved site. Pesticides that can be legally applied to areas adjacent to the test plots can be disposed of in this manner. Carefully read and follow all directions for proper disposal listed on the label. Do not dump excess pesticides in or along field margins, fence rows, or grass waterways. Illegal residues, water contamination, and wildlife kill may result.

PESTICIDE TOXICITY RATINGS

Tests are performed with every pesticide to determine how toxic (poisonous) it is to rats, rabbits, guinea pigs, or other animals. These tests are helpful in determining how hazardous the pesticide probably would be to humans.



ORAL TESTS: In oral tests the animal is fed given quantites of the pesticide by mouth based on the animal's body weight. The dose is increased until the dose that will kill 50 percent of the test animals is found. This is called the oral LD_{50}. The dose is expressed in milligrams per kilogram of body weight (mg/kg). There are 1,000 mg in a gram and 454 grams in a pound. A kilogram (kg) is 2.2 pounds. Therefore, if a pesticide has an oral LD_{50} of 100, it means that it will take 100 mg (.1 gram) of the pesticide to kill five out of ten test animals weighing a kilogram (2.2 lbs.). Or, it would take five grams (about one-fifth of an ounce) of this pesticide to kill a 110-pound human. As you can see, a compound with an oral LD_{50} of 100 is dangerous since one-ninetieth of a pound (one to two teaspoons) could kill a human. The lower the LD_{50} number, the more toxic the pesticide.

DERMAL TESTS: In dermal tests the pesticide is placed on the skin of the test animal. It is covered with a bandage so the pesticide will remain on the skin for 24 hours. If it takes 100 mg of the pesticide to kill five out of ten test animals weighing one kilogram (2.2 lbs.), the dermal LD_{50} is 100.

Compounds that give off vapors, fumes, or gases are given an additional test described below.

INHALATION TESTS: Test animals are placed in an air-tight container with given quantities of the pesticide. The animals stay in the container for one hour. Inhalation values called LC_{50}'s are measured in micrograms per liter (μg). The LC_{50} is the lethal concentration that will kill 50 percent of the test animals. There are 1,000 micrograms (μg) in one milligram (mg). One liter is equal to 1.06 quarts. Therefore, an LC_{50} of 100 means that it will take 100 micrograms per one quart of air to kill five out of ten test animals when they are exposed for one hour. LC_{50} is also used in referring to toxicities to fish in water and is expressed in parts per million (PPM).

EXPERIMENTAL-USE PERMITS

An experimental-use permit allows limited field testing of an unregistered pesticide or of a registered pesticide for use not approved in connection with its registration. The permit allows limited field testing to gather data concerning efficacy and safety in support of application to register the pesticide or for expanding the label. Experimental-use permits allow the development of new, less hazardous pesticides while providing sufficient regulatory control to protect human health and the environment. Permits are issued by the Environmental Protection Agency's Office of Pesticide Programs on a temporary basis. If application of an experimental pesticide could result in any residue on or in food or feed, the Office of Pesticide Programs will set a temporary tolerance or safe residue level before issuing a permit.

Experimental-use permits *are not* required for pesticides being put through the following:

- Laboratory or greenhouse tests.
- Field tests of less than 10 acres.
- Aquatic tests of not more than one surface-acre of water.
- Experimental animals.

All field crops treated with experimental pesticide must be destroyed or consumed by experimental animals unless a tolerance or exemption from tolerance has been established. No animals may be tested if they may be used in food or feed unless a tolerance or exemption from tolerance has been established. Waters which are involved or are affected by such tests cannot be used for irrigation, drinking water supplies, or body-contact recreation activities. Tests cannot be conducted in any waters which contain or affect any fish, plants, or animals taken from recreation or commercial purposes and used for food or feed unless a tolerance or exemption from tolerance has been established.

Pesticides under experimental-use permits cannot be sold or distributed to anyone other than the participants and used only at the designated application site in accordance with the terms and conditions of the permit.

Application for an experimental-use permit should be submitted to the Registration Division, Office of Pesticide Programs, Environmental Protection Agency, Washington, D. C., at least 90 days prior to the intended date of shipment or use.

Some of the information necessary for submission to the Office of Pesticide Programs for application for an experimental-use permit is as follows:

- Name and address of applicant.
- Registration number of the product, if registered.
- Purpose or objectives of the proposed testing:
  a description of testing program,
  designation of pest(s),
  amount of pesticide to be used,
  application rates,
  application technique,
  number of acres, animals, or sites, and
  manner of supervision.
- Complete name, address, and qualifications of all participants.
- Name and address of all cooperators.
- Information on effects to target organism and phytotoxicity information.

Misuse of any pesticide under this permit may lead to civil or criminal penalties. The Office of Pesticide Programs may revoke a permit at any time if its terms are being violated, or if the testing threatens to damage the environment.

All pesticides shipped or used under an experimental-use permit must be labeled with directions and conditions for use as directed in the permit. These labeling directions and conditions must include normal labeling information plus:

- any limitations on entry of persons into treated acres,
- the prominent statement "For experimental use only."
- the experimental-use permit number, and
- the statement "Not for resale."

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